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Z-Score and Floyd Warshall Algorithms for Determining Alternative Routes of Mugging-Prone Areas in Medan City, Indonesia

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Abstract

This study analyzes and implements the Floyd Warshall algorithm using Z-Score to track alternative routes to areas in Medan City, Indonesia that are prone to mugging. The data was obtained from *Porlestabes* (Police station) Medan-Indonesia. This study employed the Z-Score rank method to rank specific values and determine the levels of crime-prone areas. The highest and lowest levels of crime-proneness were identified using the Z-Score method, and the Floyd Warshall Algorithm is used to identify alternative routes to avoid such areas. The language used in this study adheres to objective and formal writing principles, with value-neutral and clear terminology employed throughout. The results of this analysis showed that out of 99 roads across 18 districts, 4.04% of them were classified as very high prone, 9.09% as high prone, 11.11% as prone, and 75.76% as low prone. The search results from conducting alternative route analysis with the Floyd Warshall algorithm on Perintis Kemerdekaan street indicate the identification of the safest routes.

Keywords: Z-Score; Floyd Warshall; Mugging; Medan; System.

Introduction

Medan, a city in the Sumatra Utara Province of Indonesia, is plagued by crimes that frequently disrupt the local community. Medan, a city in the Sumatra Utara Province of Indonesia, is plagued by crimes that frequently disrupt the local community. Among these crimes, mugging is one of the most alarming issues affecting the city's inhabitants. Although not explicitly defined in Indonesian law, *begal* or mugging, is a term used by traditional society to describe criminals who intercept and seize victims' assets on the street. The significant acts of mugging in Medan City make people feel less safe and alert when they want to go somewhere, especially places that are prone to mugging crimes [1].

This study employed the Z-Score rank method, which ranks specific values to determine the level of mugging areas. The method identifies the highest and lowest levels of prones [2]. Technical abbreviation Z-Score was defined on first use. The prone level for each region, consisting of 18 districts in Medan City, was obtained and mapped using the Floyd Warshall algorithm. Floyd Warshall's algorithm is a shortest-path completion algorithm that determines the starting point and finds the minimum path to the destination [3]. Previous studies on alternative routes, such as, that of using the A-Star algorithm for route search [4], the Floyd Warshall algorithm for Labuan Bajo tourism [5], and the Greedy Algorithm to find a congestion level route [6]. In addition, another research identified accident-prone locations as black spots on roads [7].

This study aims to utilize the Z-Score method to rank areas in Medan City that are prone to mugging and the Floyd Warshall algorithm to identify alternative routes to avoid these high-risk areas. The criteria used for ranking are categorized into very high prone, high prone, prone, and low prone. Routes with a low prone rating are considered safe for travel.

Method

A. Research Framework

Figure 1 is the research framework for identifying alternative routes to avoid high-risk mugging areas in Medan City.

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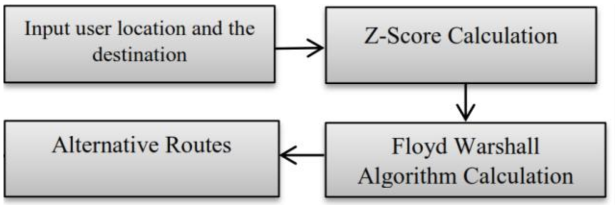

Figure 1. Research Framework

Based on **Figure 1**, the research framework commences with inputting the location and destination of user. The subsequent step is to determine the Z-Score value of the location and destination. The Floyd-Warshall algorithm process is then applied to determine alternative routes to the destination. Finally, the output displays an alternative route to the destination circumventing areas that have low incidences of mugging.

B. Z-Score

The Z-Score is a numerical value that can be either a whole number or a decimal [8]. The Z-Score method involves comparing the discrepancy between the data points and the mean distribution of the standard deviation for each specific criterion, then aggregating the results locally [9]. **Figure 2** illustrates the framework for the z-score technique utilized in this research.

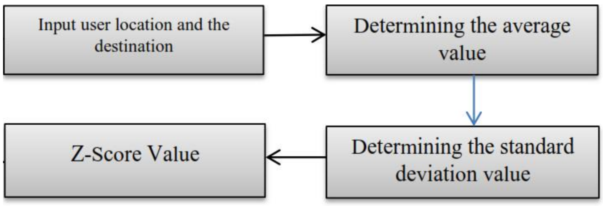

Figure 2. Framework of Z-Score method for determining alternative routes of mugging-prone areas in Medan City

Based on **Figure 2**, the initial step for performing the Z-Score technique after inputting the locations and destinations of user is to calculate the standard deviation value by obtaining the average value first. The formula presented to determine the standard deviation value is in Equation 1 [10].

$$S = \sqrt{\frac{\sum(X_i - \overline{X})^2}{n}} \quad (1)$$

Where S represents the standard deviation, X_i denotes the data amount at the i^{th} location, $\bar{X}$ is the average number of events, and n represents the amount of data. The second step is to find the Z-Score value with the formula in Equation 2 [11].

$$Z_i = \frac{X_i - \overline{X}}{S} \quad (2)$$

Where Z_i represents the Z-score of the event at the i^{th} location, and i ranges from 1 to n [12].

C. Floyd Warshall

The Floyd Warshall algorithm determines the shortest path by iterating from the starting point and extending the path by evaluating each point until it reaches the destination with the least weight [13].

$$\begin{bmatrix} 0 & n & n & n \\ n & 0 & n & n \\ n & n & 0 & n \\ n & n & n & 0 \end{bmatrix}$$

Figure 3. Matrix of results from the Floyd-Warshall algorithm.

As for this study, **Figure 4** displays the sequential stages of the Floyd Warshall algorithm. Based on the illustration in **Figure 4**, the first step in determining the shortest path using the Floyd Warshall algorithm is to represent a graph as a weighted matrix [14].

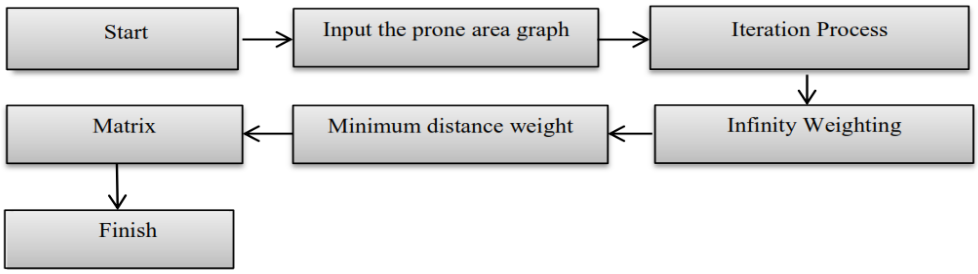

Figure 4. Floyd Warshall's Algorithmic Framework for Identifying Alternate Routes in High-Risk Mugging Areas in Medan City

The following step is to decompose the Floyd Warshall algorithm and order it $d_{jj}(k)$, where $d_{jj}(k)$ denotes the length of the shortest path from vertex i to vertex j and all intermediate vertices in the path are contained in {1, 2, 3, ..., n}. Furthermore, $d_{jj}(0)$ is consolidated at w_{jj}, which denotes that there are no intermediate vertices. Consequently, $d(k)$ becomes an $n \times n$ matrix $[d_{jj}(k)]$. Next, determine the distance from i to j (denoted as $d_{jj}(n)$), then calculate dn and dk for k = 0, 1, ..., n. The final step is to iterate from the 0^{th} to the nth iteration to calculate $D(0)$, using the weight matrix $[w_{ij}]$. To determine $D(k)$, employ the formula [15].

$$d_{jj}(k) = \min\{d_{jj}(k-1), d_{jk}(k-1) + d_{kj}(k-1)\} \qquad (3)$$

For each k value from 1 to n, where n represents the total number of vertices, Floyd Warshall's algorithm produces a matrix that reflects the final result of the iteration [16]. Using this n^{th} matrix, we can determine the shortest path for each vertex in the graph.

Results and Discussion

A. The frequency of mugging incidents in Medan City

According to the records of *Polrestabes* (Police station) Medan, the incidence of mugging cases in Medan City, from 2013 to 2019, was relatively high. The data showed that 2018 had the highest number, comprising of 46 incidents, while 2015 had the least, with 9 mugging cases.

Mugging incidents tend to happen at specific times. Data collected from mugging incidents in Medan City indicate four distinct time periods: morning (6:00-12:00), afternoon (12:00-18:00), evening (18:00-24:00), and early morning (00:00-06:00). The frequency of failure incidents based on their occurrence time is presented in **Table 1**.

Table 1. The frequency of the incidents based on the time of occurrence

Time	Year	Number of Incidents	Average
Morning	2013		
	2014	2	
	2015		
	2016		
	2017	1	
	2018	5	
	2019	1	2.25
Afternoon	2013	3	
	2014	1	
	2015		
	2016		
	2017	2	
	2018	3	
	2019	10	3.8
Evening	2013	6	
	2014	11	
	2015	3	
	2016	5	
	2017	8	
	2018	17	
	2019	10	8.6
Early Morning	2013	19	
	2014	22	

Time	Year	Number of Incidents	Average
	2015	6	
	2016	9	
	2017	14	
	2018	11	
	2019	7	12.6

According to **Table 1**, the mugging incidents had the highest frequency in the early morning, from 00:00 to 06:00 Western Indonesia Time (WIB), with an average incidence of 12.6 over 7 years. On the other hand, the morning period from 06:00 to 12:00 WIB had the lowest incident rate with an average incident of 2.25.

B. Prone Classification

Based on data regarding incidents of mugging, there are 18 districts in Medan City where such incidents have occurred, as demonstrated in **Table 2**.

Table 2. District of the Mugging Incident in Medan City

No	Districts	Year							Number of Incidents
		2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	
1	Medan Area	1	2		2	3	3		11
2	Medan Amplas	1	2				3		6
3	Medan Barat	3	4	2	3	6	4		22
4	Medan Baru		2	1	2	1	5	3	14
5	Medan Denai							3	3
6	Medan Helvetia	2	1		2	1	3	3	12
7	Medan Johor	1	1		2		1	3	8
8	Medan Kota	1	2		1	3	2	2	11
9	Medan Maimun	1	5		2	2	5		15
10	Medan Marendal				1		1		2
11	Medan Patumbak		1				1		2
12	Medan Perjuangan	3	1	1	1	1	3	3	13
13	Medan Petisah	1	2		1	1	1		6
14	Medan Polonia	1			1				2
15	Medan Sunggal	3	1		3		3	4	14
16	Medan Tembung	1	1	1	3		1	5	12
17	Medan Timur	9	9	3	3	3	5	2	34
18	PS. Tuan		1	1		4	5	7	18
	Total	**28**	**35**	**9**	**25**	**25**	**46**	**35**	**205**

The chart displaying the quantity of mugging incidents per year in Medan City is illustrated in **Figure 5**.

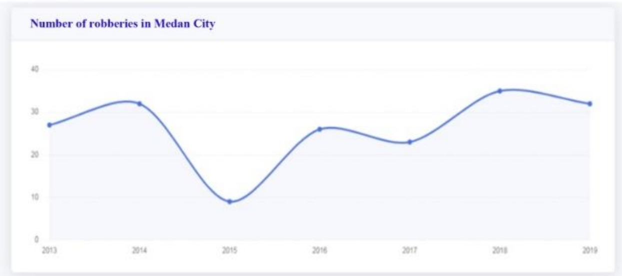

Figure 5. Number of muggings in Medan City in 2013-2019

According to **Figure 5**, there was a peak in incidents of mugging in 2018 with 46 instances, while the year with the lowest number of mugging incidents was 2015 with only 9.

C. Z-Score Analysis for Identification of Mugging-Prone Areas

To assess the level of areas at risk in each district within Medan City, the Z-Score formula is utilized. The guidelines to determine the levels of vulnerable areas through Z-Score calculation are as follows.

- *Calculating the mean value of the prone surface area*

$$\bar{X} = \frac{\sum X_i}{n} = \frac{205}{99} 2{,}07$$

The average number of mugging incidents ($\bar{X}$) is calculated by dividing the total number of mugging incidents in 2013-2019 by the total number of roads, which equals to 2.07 incidents per road.

- *Determining the Standard Deviation value*

$$S = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n}} = \sqrt{\frac{132{,}51}{99}} = 1{,}16$$

The standard deviation is calculated by subtracting the mean number of travel events (132.51) squared from the sum of squared deviations, divided by the number of data points (99), resulting in a standard deviation of 1.16.

- *Determining Z value*

The Z-Score is calculated by subtracting the average number of travel events from the average number of incidents and dividing by the standard deviation as in Equation (2).

$Z = \frac{4-2{,}07}{1{,}16} = 1{,}67$ for Gaharu Road.

$Z = \frac{1-2{,}07}{1{,}16} = -0{,}93$ for William Iskandar Road.

$Z = \frac{2-2{,}07}{1{,}16} = -0{,}06$ for Pukat Road.

$Z = \frac{5-2{,}07}{1{,}16} = 2{,}53$ for KL Yos Sudarso Road.

$Z = \frac{6-2{,}07}{1{,}16} = 3{,}40$ for Tengku Amir Hamzah Road.

We use this calculation with the incidents of mugging on Gaharu Road, William Iskandar Road, Pukat Road, KL Yos Sudarso Road, and Tengku Amir Hamzah Road, which have had 4, 1, 2, 5, and 6 incidents respectively.

- *Determining the level of risk interval*

After calculating the Z-Score value for each street, the range of mugging incidents is established and the susceptibility level is classified according to **Table 3**.

Table 3. Z-Score of mugging-prone level

No.	Z-Score Value	Information
1	3,40 – 2,53	Very High Susceptibility
2	2,53 – 1,67	High Susceptibility
3	1,67 - 0,80	Susceptible
4	0 - (-0,93)	Low Susceptibility

The Z-Score analysis results, which identify the level of mugging susceptibility in various roads throughout Medan City, are presented in **Table 4**.

Table 4. Results of Z-Score Analysis of Identifying the Level of mugging-prone in Several Roads in Medan City

No.	Road Name	X_i	$X_i - \bar{X}$	$(X_i - \bar{X})^2$	S	Z	Criteria
1	Jl.Gaharu	4	1.93	3.72	1.16	1.67	High Susceptibility
2	Jl.William Iskandar	1	-1.07	1.15	1.16	-0.93	Low Susceptibility
3	Jl. Pukat	2	-0.07	0.00	1.16	-0.06	Low Susceptibility
4	Jl. Prof HM Yamin	2	-0.07	0.00	1.16	-0.06	Low Susceptibility
5	Jl. KL Yos Sudarso	5	2.93	8.58	1.16	2.53	Very High Susceptibility
6	Jl. Malaka	2	-0.07	0.00	1.16	-0.06	Low Susceptibility

No.	Road Name	X_i	$X_i - \overline{X}$	$(X_i - \overline{X})^2$	S	Z	Criteria
7	Jl. T.Amir Hamzah	6	3.93	15.44	1.16	3.40	Very High Susceptibility
8	Jl. Bambu	4	1.93	3.72	1.16	1.67	High Susceptibility
…	…	...	…	…	…	…	…
98	Jl. A.H Nasution	2	-0.07	0.00	1.16	-0.06	Low Susceptibility
99	Jl. Sei Putih	2	-0.07	0.00	1.16	-0.06	Low Susceptibility
	Total	205		132.51			
	Average	2.07					

According to **Table 4**, the predisposing factors to mugging on 99 streets in Medan City vary from a very high susceptibility, high susceptibility, and susceptible, to a low level of susceptibility. Two roads, Tengku Amir Hamzah Road and Jamin Ginting Road, have been determined to have a very high likelihood with a Z-score of 3.40. Additionally, one road has been identified as having a low likelihood with a Z-score of -0.93.

Table 5. Results of Z-Score Analysis for Identifying the Prone Level of Each District in Medan City

No	Districts	X_i	$X_i - \overline{X}$	$(X_i - \overline{X})^2$	S	Z	Criteria
1	Medan Area	11	-0.28	0.1	7.83	-0.05	Low Susceptibility
2	Medan Amplas	6	-5.28	27.9	7.83	-0.69	Low Susceptibility
3	Medan Barat	22	10.72	114.9	7.83	1.36	High Susceptibility
4	Medan Baru	14	2.72	7.4	7. 83	0.33	High Susceptibility
5	Medan Denai	3	-8.28	68.6	7. 83	-1.07	Low Susceptibility
6	Medan Helvetia	12	0.72	0.5	7. 83	0.08	Susceptible
7	Medan Johor	8	-3.28	10.8	7. 83	-0.43	Low Susceptibility
8	Medan Kota	11	-0.28	0.1	7. 83	-0.05	Low Susceptibility
9	Medan Maimun	15	3.61	13.04	7. 83	0.46	High Susceptibility
10	Mdn Marendal	2	-9.28	86.1	7. 83	-1.20	Low Susceptibility
11	Mdn Patumbak	2	-9.28	86.1	7. 83	-1.20	Low Susceptibility
12	Mdn Perjuangan	13	1.72	3	7. 83	0.21	Susceptible
13	Medan Petisah	6	-5.28	27.9	7. 83	-0.69	Low Susceptibility
14	Medan Polonia	2	-9.28	86.1	7. 83	-1.20	Low Susceptibility
15	Medan Sunggal	14	2.61	6.82	7. 83	0.33	Susceptible
16	Medan Tembung	12	0.72	0.5	7. 83	0.08	Low Susceptibility
17	Medan Timur	34	22.72	516.2	7. 83	2.89	Very High Susceptibility
18	PS. Tuan	18	6.72	45.2	7. 83	0.84	High Susceptibility
	Total	205		1102.28			
	Average $\sum(X_i - \overline{X})^2 / 18$	11.39		61.24			

According to **Table 5**, the 18 districts in Medan City have been categorized into four groups based on their susceptibility to mugging: Very High Susceptibility, High Susceptibility, Susceptible, and Low Susceptibility. The district with the highest vulnerability is Medan Timur, with a Z-Score value of 2.89. Conversely, Medan Marendal, Medan Patumbak, and Medan Polonia are the districts with the lowest vulnerability, as they all have a Z-Score value of -1.20. After acquiring the vulnerability level data for every road in Medan City through the Z-Score method, the next step involved linking the data of roads fulfilling the criteria for very high, high, and prone areas using the Floyd Warshall algorithm. If the Floyd Warshall algorithm passes through a vulnerable point in specific regions, it automatically displays a warning sign indicating the road is unsafe to pass. This occurs because the road meets the criteria for a vulnerable area, and the algorithm provides safe route information for the public and tourists to use.

The Z-Score method was employed in this study to rank each area prone to mugging, from the highest level of risk to the lowest. Alternative routes were then considered using the Floyd Warshall algorithm for routes that are frequently targeted by muggers.

D. Implementing the Floyd Warshall Algorithm

The Floyd Warshall algorithm was implemented as an alternative route search algorithm to avoid areas in Medan City that are prone to mugging.

- *Graph Implementation of Routes*

  To calculate an alternative route via the Floyd Warshall algorithm, the initial step is to establish a graph of paths or routes that need traversing, represented in **Figure 6**.

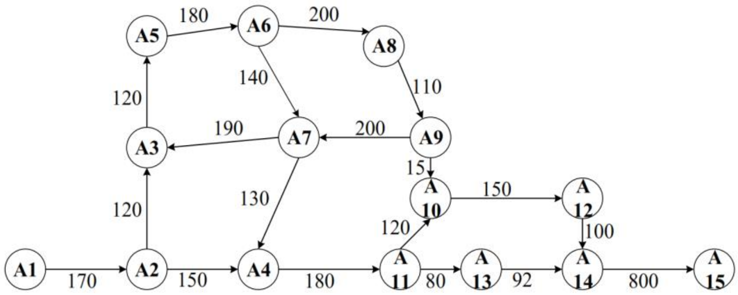

Figure 6. Graph of areas in Medan city with high incidence of mugging.

Based on **Figure 6**, the graph displays intersection names represented by nodes and path names represented by numbers at each node. Node A13 designates the location of the prone area. Refer to **Table 6** for a comprehensive list of nodes and path names.

Table 6. List of nodes in graph modelling

No.	Node	Crossroad Name
1	A1	Jl. Putri merak jingga - Jl. Perintis kemerdekaan
2	A2	Jl. Perintis kemerdekaan - Jl. Gaharu
3	A3	Jl. Gaharu - Jl. Mahoni
4	A4	Jl. Perintis kemerdekaan - Jl. Timor
5	A5	Jl. Gaharu - Jl. Tusam
6	A6	Jl. Tusam - Jl. Timor
7	A7	Jl. Mahoni - Jl. Timor
8	A8	Jl. Tusam - Jl. Sutomo
9	A9	Jl. Mahoni - Jl. Sutomo
10	A10	Jl. Sutomo - Jl. IAIN
11	A11	Jl. Perintis kemerdekaan - Jl. Sutomo
12	A12	Jl. IAIN - Jl. Adinegoro
13	A13	Prone Points
14	A14	Jl. Adinegoro - Jl. Perintis kemerdekaan
15	A15	Jl. Perintis kemerdekaan

- *Implementation of Route Weights into a Matrix*

Route weights are implemented after determining the prone area graph, which is transformed into a matrix based on the number of graph nodes. **Figure 7** displays the matrix of this route graph.

$$
\begin{bmatrix}
0 & 170 & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
170 & 0 & 120 & 170 & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
\infty & 120 & 0 & \infty & 120 & \infty & 190 & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
\infty & 170 & \infty & 0 & \infty & \infty & 130 & \infty & \infty & \infty & 200 & \infty & \infty & \infty & \infty \\
\infty & \infty & 120 & \infty & 0 & 180 & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
\infty & \infty & \infty & \infty & 180 & 0 & 170 & 200 & \infty & \infty & \infty & \infty & \infty & \infty & \infty \\
\infty & \infty & 190 & 130 & \infty & 120 & 0 & \infty & 200 & \infty & \infty & \infty & \infty & \infty & \infty \\
\infty & \infty & \infty & \infty & \infty & 200 & \infty & 0 & 110 & \infty & \infty & \infty & \infty & \infty & \infty \\
\infty & \infty & \infty & \infty & \infty & \infty & 200 & 110 & 0 & 15 & \infty & \infty & \infty & \infty & \infty \\
\infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & 15 & 0 & 120 & 170 & \infty & \infty & \infty \\
\infty & \infty & \infty & 200 & \infty & \infty & \infty & \infty & \infty & 120 & 0 & \infty & 80 & \infty & \infty \\
\infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & 170 & \infty & 0 & \infty & 120 & \infty \\
\infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & 80 & \infty & 0 & 92 & \infty \\
\infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & 120 & 92 & 0 & 800 \\
\infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & \infty & 800 & 0
\end{bmatrix}
$$

Figure 7. Matrix results of the Floyd Warshall algorithm

After inserting the route weights into a matrix, the value of the infinite weight can be obtained by iterating from the 0th iteration up to the nth iteration, where 'n' is the number of existing vertices, using Equation 3. The 15^{th} iteration in **Figure 8** shows the alternative routes.

A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15
0	170	290	340	410	590	470	780	670	660	540	830	620	712	1512
170	0	120	170	240	420	300	610	500	490	370	660	450	542	1342
290	1120	0	290	120	300	190	500	390	405	490	575	570	662	1462
340	170	290	0	410	250	130	440	330	320	200	490	280	372	1172
410	240	120	410	0	180	310	380	490	505	610	675	690	782	1582
590	420	300	300	180	0	170	200	310	325	445	495	525	615	1415
470	300	190	130	300	120	0	310	200	215	330	385	410	502	1302
780	610	500	440	380	200	310	0	310	125	245	295	325	415	1215
670	500	390	330	490	310	200	110	0	15	135	185	215	305	1105
660	490	405	320	505	325	215	125	15	0	120	170	200	290	1090
540	370	490	200	610	445	330	245	135	120	0	290	80	172	972
830	660	575	490	675	495	385	295	185	170	290	0	212	120	920
620	450	570	280	690	525	410	325	215	200	80	212	0	92	892
712	542	662	372	782	615	502	415	305	290	172	120	92	0	800
1512	1342	1462	1172	1582	1415	1302	1215	1105	1090	972	920	892	800	0
A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15

Figure 8. Matrix results for iterations 1 through 15 of the Floyd Warshall algorithm.

In the final iteration matrix, there exists a viable path to travel from vertex A1 to vertex A15 whilst avoiding the hazardous area at vertex A13. According to the Floyd Warshall algorithm calculations, the distances between each vertex are as follows.

$$W(A1,A2) + W(A2,A4) + W(A4,A11) + W(A11,A10) + W(A10,12) + W(A12,A14) + W(A14,15)$$
$$= 170 + 170 + 200 + 120 + 290 + 120 + 800$$
$$= 1870\ m.$$

Figure 9. Alternative Route

Conclusion

The Z-Score method facilitates ranking of routes in vulnerable zones, so that the Floyd Warshall algorithm can generate alternative routes for each of them. Floyd Warshall algorithm produces alternative routes based on users locations and destinations. The research data comprises 99 routes categorized under four levels of vulnerability to mugging, i.e., very high (4.04%), high (9.09%), prone (11.11%), and low (75.76%), and covers 18 districts of Medan City. The test results of the Floyd Warshall algorithm on the Perintis Kemerdekaan street indicate that there are alternative safe output routes available through the IAIN street, avoiding the more vulnerable points. The highest Z-Score value recorded is 3.40, indicating a very high propensity for vulnerability, while the lowest score is -0.93, denoting a low propensity.

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